SEISMIC ANALYSIS OF PILE GROUPS DUE TO NONLINEAR SOIL-PILE KINEMATIC INTERACTION

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The dynamic response of piles during transient earthquake motions has received large attention in recent years and several researchers have investigated the nature of input ground motion and the mechanism of soil-pile interaction to determine seismic design loads for pile supported structures. During earthquakes, piles undergo stresses due both motion of the superstructure (i.e. inertial interaction) and that of the surrounding soil (i.e. kinematic interaction). In practice, structural engineers commonly take into account stresses induced by the inertial interaction, which may be responsible for pile head failure, but they neglect the effects of the kinematic interaction that may be responsible for failures along pile's length in the case of layered soils with highly contrasting mechanical characteristics and may result somewhat important even in the absence of the superstructure. Thus, the evaluation of kinematic forces developing in piles during earthquakes has been receiving increased interest from researchers.

Numerical methods for the analysis of kinematic soil-pile interaction may be classified into two groups; continuum-based approach (FEM, BEM) and Winkler methods (Wu and Finn, 1997; Maiorano et al., 2007; Nikolau et al., 2001; Dezi et al., 2009; etc.). Most of the available researches have been focused on the linear soil-pile group problem. However under strong excitation, the nonlinear behaviour of the soil media at the soil-pile interface has a strong influence on the response of the pile foundation. Therefore the aim of this study is to investigate the influence of soil nonlinearities on the kinematic interaction forces of pile groups embedded in layered soil deposits during seismic actions. A 3D finite element model has been used for the analyses performed in the time domain. The pile has been considered as an elastic beam, while the soils have been modelled using the elastic-plastic solid element. Figure 1 shows an assumed typical soil-pile group case with 5 by 5 piles and the space–diameter ratio s/d set at about 3.6 embedded in two layer subsoil profile. The corresponding finite element mesh has been shown in Figure 2. Based on symmetry, only half of the model is meshed.

Dynamic numerical analysis has been performed using the FE program ABAQUS. Necessary parameters to simulate the examined cases are listed in Table 1. The simulated models allow calculating the internal forces induced by soil–pile and pile-to-pile interactions. It is mentioned that comparisons with available results in literature have been made to validate the models. The models have the potential to catch the dynamic behaviour of the soil–foundation system and the stress resultants in each pile. The representative kinematic bending moments and axial forces along piles depth are reported in Figure 3 for the 1978 Tabas, Iran earthquake at Dayhook station. It is observed that the kinematic force distributions present relative maximum values at the interface between the two layers. Note that according to the numerical results, these kinematic forces are also different from those obtained with linear analysis. In addition, the effects of kinematic group interaction lead to a decrease of bending moments at the pile head and the layer interface as compared to the existing results from single pile.

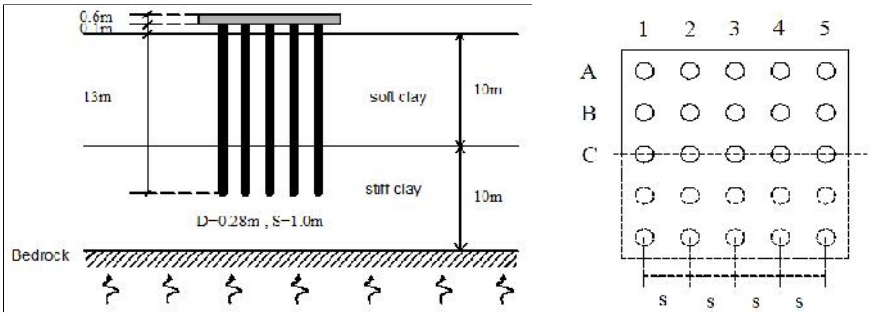


Figure 1. Typical soil-pile group model

Table 1. Geotechnical parameters of the soils and piles

Model elements	material	Density ρ (Kg/m^3)	Poisson's ratio ν	friction angle, Φ (deg)	Dilatancy angle, ψ (deg)	Young modulus, E (Mpa)	Damping ratio, ξ	s-wave velocity v(m/s)
One layer	Soft clay	2100	0.49	0	0	100	0.05	126
Two layer	stiff clay	2500	0.4	0	0	4.48×10^3	0.02	800
Piles , cap	steel	7100	0.3	-	-	2.1×10^5	-	-

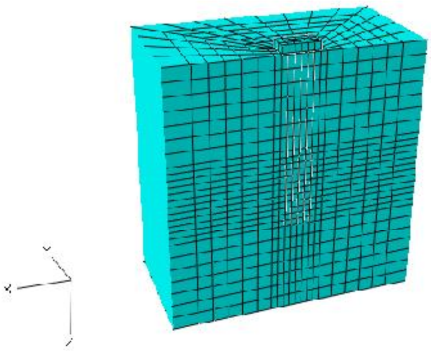
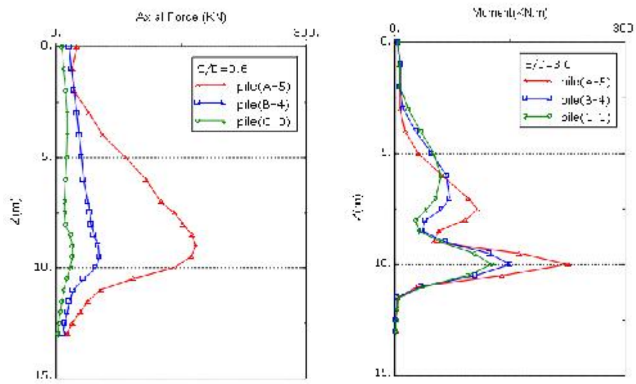


Figure 2. FE model for soil-pile group with 5 by5 piles



(a) (b)

Figure 3. Kinematic internal envelope forces in pile group (a) bending moments (b) axial force

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